CLAIMS

1. A spindle unit comprising:

a rolling bearing including an outer ring having an outer ring raceway on an inner peripheral surface, an inner ring having an inner ring raceway on an outer peripheral surface, and rolling elements provided rollably between the outer ring raceway and the inner ring raceway, whereby a spindle is borne rotatably in a housing; and

a grease supply system for supplying a grease to an inside of the rolling bearing;

wherein the grease supply system supplies the grease such that a supply amount in one shot is set to 0.004 cc to 0.1 cc.

2. A spindle unit according to claim 1, wherein the grease supply system contains a supply hole provided in the outer ring.

3. A spindle unit according to claim 1, further comprising an outer ring spacer;

wherein the grease supply system contains a supply hole provided in the outer ring spacer.

4. A spindle unit according to claim 1, wherein the grease supply system contains a supply hole provided in the housing.

5. A spindle unit according to claim 1, further comprising at least one rotating body arranged in vicinity of a side surface of the inner ring or the outer ring; and

wherein the grease is exhausted to an outside of the rolling bearing by a rotation of the rotating body.

6. A spindle unit according to claim 5, wherein a storage space for storing the exhausted grease is provided in the housing.

7. A spindle unit according to claim 1, further comprising at least one exhaust hole for exhausting the grease to an outside of the spindle unit; and

wherein the grease is stored in the exhaust hole.

8. A spindle unit according to any one of claims 5 to 7, wherein the rotating body is composed of a collar that is formed in at least one of an inner ring spacer, the inner ring, and a cage of the rolling bearing.

9. A spindle unit according to claim 7 or 8, wherein the grease is exhausted by pouring another fluid different from the grease into the exhaust hole from an outside.

10. A spindle unit according to claim 1, further comprising a rotation speed sensor for sensing a rotation speed of the spindle; and

wherein the grease supply system supplies the grease into an inside of

the rolling bearing in response to the rotation speed.

11. A spindle unit according to claim 10, wherein the grease supply system divides the rotation speed into a plurality of areas to assign an addend to the plurality of areas respectively, then calculates an integrated value by integrating the addend corresponding to the measured rotation speed every unit time, and then supplies the grease when the integrated value exceeds a predetermined value.

12. A spindle unit according to claim 11, wherein the grease supply system resets the integrated value at a time of grease supply, and integrates a number of resets of the integrated value.

13. A spindle unit according to claim 11 or 12, wherein the grease supply system sets the addend to 0 and does not executes an integration when the spindle is stopped.

14. A spindle unit according to any one of claims 10 to 13, wherein the grease supply system controls the rotation speed of the spindle smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value.

15. A spindle unit according to any one of claims 11 to 13, wherein the grease supply system controls the rotation speed of the spindle smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value, and

the predetermined rotation speed belongs to a rotation speed area that is one rank lower than a maximum rotation speed area in the plurality of areas.

16. A spindle unit according to claim 1, wherein the grease supply system includes a mechanical fixed-displacement piston pump having a check valve and a fixed-displacement piston to discharge the grease, a grease tank for storing the grease, an in-grease-tank piston for pressurizing the grease in the grease tank, and a sensor provided to the grease tank to monitor a residual amount of grease.

17. A spindle unit according to claim 16, wherein the sensor has a magnet that is fitted to the in-grease-tank piston.

18. A spindle unit according to claim 16 or 17, further comprising a sensor for monitoring a pressure of the grease in the grease tank or a pressure of the grease in a grease piping that connects the mechanical fixed-displacement piston pump and the grease tank.

19. A spindle unit according to any one of claims 16 to 18, further comprising a mechanism for holding a pressure applied to the in-grease-tank

piston for a predetermined time to pressurize the grease in the grease tank in a state that the fixed-displacement piston returns to a home position after the mechanical fixed-displacement piston pump operates to discharge the grease.

20. A spindle unit according to any one of claims 16 to 19, wherein the sensor controls an upper limit of the rotation speed of the spindle when the sensor senses an abnormality.

21. A spindle unit according to claim 1, wherein the grease supply system includes a mechanical fixed-displacement piston pump having a grease tank for storing the grease, a cylinder for containing the grease fed from the grease tank by a predetermined amount, a fixed-displacement piston moved reciprocally in the cylinder to discharge the grease contained in the cylinder in a predetermined amount to a grease supply piping, and a check valve arranged onto an end portion of the cylinder.

22. A spindle unit according to claim 21, wherein the mechanical fixed-displacement piston pump has a valve for supplying a medium into the cylinder, and the fixed- displacement piston is operated by the medium supplied via the valve.

23. A spindle unit according to claim 21 or 22, wherein the grease supply piping is formed of a Teflon tube.

24. A spindle unit according to claim 1, further comprising a cooling means for cooling a predetermined location by supplying a cooling fluid to an inside of the housing; and a motor having a rotor provided to the spindle and a stator provided to an inner peripheral surface of the housing to oppose to the rotor;

wherein the spindle is operated by the motor, and

the cooling means cools the stator and also cools at least the outer ring of the rolling bearing.

25. A spindle unit according to claim 24, wherein the cooling means cools the spindle by supplying the cooling fluid to an inside of the spindle and passing the cooling fluid through the spindle in a longitudinal direction.

26. A spindle unit according to claim 24 or 25, further comprising a cooling fluid recovering means for recovering the cooling fluid exhausted from the spindle and the housing.

27. A spindle unit according to claim 1, wherein the rolling bearing includes at least one supply hole formed in the outer ring to supply the grease to an inside of the rolling bearing, and an annular groove formed on an outer periphery of the outer ring to contain the supply hole, and

a value obtained by dividing a sectional area (mm^2) of the annular

groove by a peripheral length (mm) of a cross section of the annular groove is set to 0.25 mm or more.

28. A spindle unit according to claim 1, wherein the rolling bearing includes at least one supply hole formed in the outer ring to supply the grease to an inside of the rolling bearing,

the housing includes an annular groove formed on an inner periphery of the housing to face to the supply hole, and

a value obtained by dividing a sectional area (mm^2) of the annular groove by a peripheral length (mm) of a cross section of the annular groove is set to 0.25 mm or more.

29. A spindle unit according to claim 27 or 28, wherein a pair of outer annular grooves are formed on an outer periphery of the outer ring or an inner periphery of the housing on both sides of the supply hole in an axial direction, and an O ring is fitted into the pair of outer annular grooves respectively.

30. A spindle unit according to claim 27 or 28, wherein a clearance between the inner periphery of the housing and the outer periphery of the outer ring is set to 30 μ m or less, and a length of a contact portion between an outer diameter surface of the outer ring and the housing in the axial direction is set to 1 mm or more.

31. A spindle unit according to any one of claims 1 to 30, wherein the spindle is a machine tool spindle.

32. A spindle unit according to any one of claims 1 to 30, wherein the spindle is a high-speed motor spindle.

33. A spindle unit comprising:

a rolling bearing including an outer ring having an outer ring raceway on an inner peripheral surface, an inner ring having an inner ring raceway on an outer peripheral surface, and rolling elements provided rollably between the outer ring raceway and the inner ring raceway, whereby a spindle is borne rotatably in a housing; and

a lubricant supplying path for supplying a lubricant to an inside of the rolling bearing from an outside; and

a rotating body arranged in vicinity of a side surface of the inner ring or the outer ring;

wherein the lubricant is exhausted to an outside of the rolling bearing by a rotation of the rotating body.

34. A spindle unit according to claim 1, wherein a storage space for storing the exhausted lubricant is provided to the housing.

35. A spindle unit according to claim 34, further comprising at least

one exhaust hole for exhausting the lubricant from the storage space to an outside of the spindle unit; and

wherein the lubricant is stored in the exhaust hole.

36. A spindle unit according to claim 34 or 35, wherein the rotating body is composed of a collar that is formed in at least one of an inner ring spacer, the inner ring, and a cage of the rolling bearing.

37. A spindle unit according to any one of claims 34 to 36, wherein the rotating body is composed of a collar that is formed in at least one of an inner ring spacer, the inner ring, and a cage of the rolling bearing.

38. A spindle unit according to any one of claims 33 to 37, wherein the spindle is a machine tool spindle.

39. A spindle unit according to any one of claims 33 to 37, wherein the spindle is a high-speed motor spindle.

40. A spindle unit comprising a cutting fluid sensor provided to a cutting fluid entering area extended from a clearance between a spindle and a front end of a housing to a rolling bearing.

41. A spindle unit according to claim 40, wherein the cutting fluid sensor is provided in an area between a labyrinth seal and the rolling bearing.

42. A spindle unit according to claim 40 or 41, wherein a drain path is opened in the cutting fluid entering area, and the cutting fluid sensor is provided in the drain path.

43. A spindle unit according to any one of claims 40 to 41, wherein an exhaust valve is provided to the drain path.

44. A spindle unit according to claim 43, wherein the exhaust valve is operated based on a sensed signal of the cutting fluid sensor to exhaust the cutting fluid from the cutting fluid entering area.

45. A spindle unit according to any one of claims 40 to 44, wherein a lubricant supply hole is formed in the rolling bearing, then the lubricant supply hole is connected to a lubricant supply system, and then the lubricant supply system is operated based on a sensed signal of the cutting fluid sensor to supply the lubricant to the rolling bearing.

46. A spindle unit according to claim 40, wherein the spindle unit is used in a machine tool that has a function of limiting conditions to running conditions, in which the rolling bearing is not damaged, in response to a signal of the cutting fluid sensor.

47. A spindle unit according to claims 40 to 46, further comprising a warning means for displaying a warning message based on a sensed signal of the cutting fluid sensor.

48. A spindle unit comprising:

a housing onto which a rolling bearing is fitted;

a spindle passed through the rolling bearing;

a grease supply system for supplying a grease to a bearing space of the rolling bearing to lubricate the bearing with the grease; and

a cooling means for cooling a predetermined location by supplying a cooling fluid to an inside of the housing;

wherein the spindle is operated by a motor that has a rotor provided to the spindle and a stator provided to an inner peripheral surface of the housing to oppose to the rotor, and

wherein the cooling means cools the stator and cools at least a fixed-side bearing of the rolling bearing.

49. A spindle unit according to claim 48, wherein the cooling means cools the spindle by supplying the cooling fluid to an inside of the spindle and passing the cooling fluid through the spindle in a longitudinal direction.

50. A spindle unit according to claim 48 or 49, further comprising a cooling fluid recovering means for recovering the cooling fluid exhausted from the spindle and the housing.

51. A spindle unit according to any one of claims 48 to 50, wherein the spindle is a machine tool spindle.

52. A spindle unit according to any one of claims 48 to 50, wherein the spindle is a high-speed motor spindle.

53. A grease supply system comprising:

a grease supply mechanism for supplying a grease to an inside of a rolling bearing that has an outer ring having an outer ring raceway on an inner peripheral surface, an inner ring having an inner ring raceway on an outer peripheral surface, rolling elements provided rollably between the outer ring raceway and the inner ring raceway; and

wherein the grease supply mechanism supplies the grease such that a supply amount in one shot is set to 0.004 cc to 0.1 cc.

54. A grease supply system according to claim 53, wherein the grease supply mechanism contains a supply hole provided to the outer ring.

55. A grease supply system according to claim 53, wherein the grease supply mechanism contains a supply hole provided to an outer ring spacer in vicinity of the rolling bearing.

56. A grease supply system according to claim 53, wherein the rolling bearing is a roller bearing in which the rolling elements are rollers.

57. A grease supply system according to claim 53, wherein the rolling

bearing is an angular contact ball bearing that has a contact angle and has balls as the rolling elements, and

the grease supply mechanism contains a supply hole that is opened to a location that is deviated from contact portions between the outer ring raceway and the balls.

58. A grease supply system according to any one of claims 53 to 57, wherein a diameter of the supply hole is set in a range of 0.1 to 5 mm.

59. A grease supply system according to claim 53, wherein the rolling bearing bears rotatably the spindle, and

further comprising a controlling means for controlling a supply timing to supply the grease in response to a rotation speed of the spindle.

60. A grease supply system according to claim 59, wherein the controlling means divides the rotation speed into a plurality of areas to assign an addend to the plurality of areas respectively, then calculates an integrated value by integrating the addend corresponding to the measured rotation speed every unit time, and then instructs the grease supply mechanism to supply the grease when the integrated value exceeds a predetermined value.

61. A grease supply system according to claim 60, wherein the controlling means resets the integrated value at a time of grease supply, and integrates a number of resets of the integrated value.

62. A grease supply system according to claim 60 or 61, wherein the controlling means sets the addend to 0 and does not executes an integration when the spindle is stopped.

63. A grease supply system according to any one of claims 59 to 62, wherein the controlling means controls the rotation speed of the spindle smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value.

64. A grease supply system according to any one of claims 60 to 62, wherein the controlling means controls the rotation speed of the spindle smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value, and

the predetermined rotation speed belongs to a rotation speed area that is one rank lower than a maximum rotation speed area in the plurality of areas.

65. A grease supply system according to claim 53, wherein the grease supply mechanism includes a mechanical fixed- displacement piston pump having a check valve and a fixed- displacement piston to discharge the grease, a grease tank for storing the grease, an in-grease-tank piston for pressurizing

the grease in the grease tank, and a sensor provided to the grease tank to monitor a residual amount of grease.

66. A grease supply system according to claim 65, wherein the sensor has a magnet that is fitted to the in-grease-tank piston.

67. A grease supply system according to claim 65 or 66, further comprising a sensor for monitoring a pressure of the grease in the grease tank or a pressure of the grease in a grease piping that connects the mechanical fixed-displacement piston pump and the grease tank.

68. A grease supply system according to any one of claims 65 to 67, further comprising a mechanism for holding a pressure applied to the in-grease-tank piston for a predetermined time to pressurize the grease in the grease tank in a state that the fixed-displacement piston returns to a home position after the mechanical fixed-displacement piston pump operates to discharge the grease.

69. A grease supply system according to claim 53, wherein the grease supply mechanism includes a mechanical fixed- displacement piston pump having a grease tank for storing the grease, a cylinder for containing the grease fed from the grease tank by a predetermined amount, a fixed-displacement piston moved reciprocally in the cylinder to discharge the grease contained in the cylinder in a predetermined amount to a grease supply piping, and a check valve arranged onto an end portion of the cylinder.

70. A grease supply system according to claim 69, wherein the mechanical fixed-displacement piston pump has a valve for supplying a medium into the cylinder, and the fixed- displacement piston is operated by the medium supplied via the valve.

71. A grease supply system according to claim 69 or 70, wherein the grease supply piping is formed of a Teflon tube.

72. A grease supply system according to claim 53, wherein the grease supply mechanism includes at least one supply hole formed in the outer ring to supply the grease to an inside of the rolling bearing, and an annular groove formed on an outer periphery of the outer ring to contain the supply hole, and

a value obtained by dividing a sectional area (mm^2) of the annular groove by a peripheral length (mm) of a cross section of the annular groove is set to 0.25 mm or more.

73. A grease supply system according to claim 53, wherein the grease supply mechanism includes at least one supply hole formed in the outer ring to supply the grease to an inside of the rolling bearing, and an annular groove formed on an inner periphery of the housing, which supports the spindle via

the rolling bearing, to face to the supply hole, and

a value obtained by dividing a sectional area (mm^2) of the annular groove by a peripheral length (mm) of a cross section of the annular groove is set to 0.25 mm or more.

74. A grease supply system according to claim 72 or 73, wherein a pair of outer annular grooves are formed on an outer periphery of the outer ring or an inner periphery of the housing on both sides of the supply hole in an axial direction, and an O ring is fitted into the pair of outer annular grooves respectively.

75. A grease supply system according to claim 72 or 73, wherein a clearance between the inner periphery of the housing and the outer periphery of the outer ring is set to 30 μm or less, and a length of a contact portion between an outer diameter surface of the outer ring and the housing in the axial direction is set to 1 mm or more.

76. A machine tool spindle unit using the grease supply system set forth in any one of claims 53 to 75.

77. A high-speed motor spindle unit using the grease supply system set forth in any one of claims 53 to 75.

78. A grease supply system comprising:

a grease supply mechanism for supplying an additional grease to an inside of a rolling bearing that bears rotatably a spindle; and

a controlling means for controlling a supply timing at which the grease supply mechanism supplies the additional grease in response to a rotation speed of the spindle.

79. A grease supply system according to claim 78, wherein the controlling means divides the rotation speed into a plurality of areas to assign an addend to the plurality of areas respectively, then calculates an integrated value by integrating the addend corresponding to the measured rotation speed every unit time, and then instructs the grease supply mechanism to supply the additional grease when the integrated value exceeds a predetermined value.

80. A grease supply system according to claim 79, wherein the controlling means resets the integrated value at a time of grease supply, and integrates a number of resets of the integrated value.

81. A grease supply system according to claim 79 or 80, wherein the controlling means sets the addend to 0 and does not executes an integration when the spindle is stopped.

82. A grease supply system according to any one of claims 78 to 81, wherein the controlling means controls the rotation speed of the spindle

smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value.

83. A grease supply system according to any one of claims 79 to 81, wherein the controlling means controls the rotation speed of the spindle smaller than a predetermined rotation speed when a residual amount of grease in the grease supply system is reduced smaller than a predetermined value, and

the predetermined rotation speed belongs to a rotation speed area that is one rank lower than a maximum rotation speed area in the plurality of areas.

84. A machine tool spindle unit using the grease supply system set forth in any one of claims 78 to 83.

85. A high-speed motor spindle unit using the grease supply system set forth in any one of claims 78 to 83.

86. A grease supply method of supplying an additional grease to a grease-lubricated rotating body, comprising:

a step of dividing a rotation speed into a plurality of areas;

a step of assigning an addend to the plurality of areas respectively;

a step of measuring an actual rotation speed of the rotating body every unit time;

a step of deciding to which area of the plurality of areas the actual rotation speed belongs;

a step of calculating an integrated value by integrating the addend corresponding to the area that contains the actual rotation speed; and

a step of issuing an instruction to supply an additional grease when the integrated value exceeds a predetermined value.

87. A grease supply method according to claim 86, wherein the integrated value is reset at a time of grease supply, and a number of resets of the integrated value is integrated.

88. A grease supply method according to claim 86 or 87, wherein the addend is set to 0 and an integration is not executed when the spindle is stopped.

89. A grease supply method according to any one of claims 86 to 88, further comprising a step of controlling the actual rotation speed smaller than a predetermined rotation speed when a residual amount of grease is reduced smaller than a predetermined value.

90. A grease supply method according to claim 89, wherein the predetermined value of the actual rotation speed belongs to a rotation speed area that is one rank lower than a maximum rotation speed area in the

plurality of areas.

91. A machine tool spindle unit using the grease supply method set forth in any one of claims 86 to 90.

92. A high-speed motor spindle unit using the grease supply method set forth in any one of claims 86 to 90.

93. A grease supply program of supplying an additional grease to a grease-lubricated rotating body, and causing a computer to execute

a step of dividing a rotation speed into a plurality of areas,

a step of assigning an addend to the plurality of areas respectively,

a step of measuring an actual rotation speed of the rotating body every unit time,

a step of deciding to which area of the plurality of areas the actual rotation speed belongs,

a step of calculating an integrated value by integrating the addend corresponding to the area that contains the actual rotation speed, and

a step of issuing an instruction to supply an additional grease when the integrated value exceeds a predetermined value.

94. A grease supply program according to claim 93, wherein the integrated value is reset at a time of grease supply, and a number of resets of the integrated value is integrated.

95. A grease supply program according to claim 93 or 94, wherein the addend is set to 0 and an integration is not executed when the spindle is stopped.

96. A grease supply program according to any one of claims 93 to 95, wherein further comprising a step of controlling the actual rotation speed smaller than a predetermined rotation speed when a residual amount of grease is reduced smaller than a predetermined value.

97. A grease supply program according to claim 96, wherein the predetermined value of the actual rotation speed belongs to a rotation speed area that is one rank lower than a maximum rotation speed area in the plurality of areas.

98. A machine tool spindle unit using the grease supply program set forth in any one of claims 93 to 97.

99. A high-speed motor spindle unit using the grease supply program set forth in any one of claims 93 to 97.

100. A grease supply system comprising:

a mechanical fixed-displacement piston pump having a check valve and a fixed-displacement piston to discharge the grease;

a grease tank for storing the grease;

an in-grease-tank piston for pressurizing the grease in the grease tank; and

a sensor provided to the grease tank to monitor a residual amount of grease.

101. A grease supply system according to claim 100, wherein the sensor has a magnet that is fitted to the in-grease-tank piston.

102. A grease supply system according to claim 100 or 101, further comprising a mechanism for holding a pressure applied to the in-grease-tank piston for a predetermined time to pressurize the grease in the grease tank in a state that the fixed-displacement piston returns to a home position after the mechanical fixed-displacement piston pump operates to discharge the grease.

103. A grease supply system according to any one of claims 100 to 102, further comprising a mechanism for holding a pressure applied to the in-grease-tank piston for a predetermined time to pressurize the grease in the grease tank in a state that the fixed-displacement piston returns to a home position after the mechanical fixed-displacement piston pump operates to discharge the grease.

104. A machine tool spindle unit using the grease supply system set forth in any one of claims 100 to 103.

105. A high-speed motor spindle unit using the grease supply system set forth in any one of claims 100 to 103.

106. A spindle unit according to claim 104 or 105, wherein the sensor controls an upper limit of a rotation speed when the sensor senses an abnormality.